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IMPLEMENTATION OF THE DREO PLANS (PRIMARY LAND ARCTIC NAVIGATION SYSTEM) EXPERIMENTAL DEVELOPMENT MODEL

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REPORT NO. 987

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ABSTRACT

This Report gives a brief background summary of the PLANS development program, and provides a general description of the DREO Experimental Development Model (XDM) of a Primary Land Arctic Navigation System (PLANS). This includes a generic description of the essential PLANS hardware requirements (processors, memory, interfaces, displays, sensors etc.) as well as the specific hardware used in the XDM. A high level description of the software structure and data flow is given. A brief general description of the salient functional characteristics of PLANS is presented, including the accuracy performance. Also provided is an extensive list of references for further detailed information on the various components of the PLANS XDM.

RÉSUMÉ

Ce rapport donne une brève description du programme de développement de PLANS ainsi qu'une description générale du modèle de développement expérimental d'un système de navigation terrestre pour l'artique (PLANS) développé au CRDO. Les exigences minimales pour les composantes de PLANS (processeur, mémoire, interfaces, affichages, senseurs, etc.) sont discutées, ainsi que les composantes spécifiques utilisées pour le modèle de développement. Une description générale du logiciel est donnée. Un résumé des principales caractéristiques fonctionnelles de PLANS sont présentées, incluant la précision du système. Une liste de références est incluse, fournissant plus d'information sur les diverses composantes du système.

EXECUTIVE SUMMARY

The Canadian Forces Mobile Command has had a longstanding requirement for an Arctic navigation system. In December 1982 DLAEEM 3-2 tasked DREO with the development of a Primary Land Arctic Navigation System (PLANS) to meet this requirement. DREO has therefore designed and prototyped a PLANS, based on the optimal (Kalman filter based) integration of a carefully chosen set of sensors. This design, in the form of an experimental development model (XDM) has been shown through field trials at DREO, Petawawa and Iqaluit (Frobisher Bay) to meet the basic functional and accuracy requirements, but has not been evaluated against the environmental requirements.

The sensors chosen for PLANS are all commercially available, and they fall into two categories: the self contained dead reckoning (DR) sensors and the external aiding sensors. The primary self contained sensors are the vehicle odometer and a gyro unit. These measure the vehicle velocity, from which the position can be determined from a known starting point. This DR solution is aided by another self contained sensor: a magnetic heading sensor, which can be used to initialize the gyro heading at extreme latitudes (where the gyro unit may be unable to adequately perform the necessary gyrocompassing to find the initial heading).

The external aiding sensors are satellite positioning systems, which rely on radio transmissions from the Transit or GPS satellites. The initial PLANS design relied on Transit, which produces a position fix roughly once every hour. The GPS receiver produces more accurate position fixes, and they are essentially continuous when a sufficient number of GPS satellites are visible. As more GPS satellites are launched, the gaps in visibility will decrease and disappear, at which point the Transit receiver will no longer be required.

An essential feature of the DREO-developed PLANS is the multisensor integration Kalman filter and prefilter software, with its error detection, error correction, dynamic calibration and sensor blending. This PLANS filter and prefilter are based on detailed stochastic error models developed at DREO, as described in the DREO report of reference 2.1.2. Therefore the particular choice of sensors (ie. the brands and models) is not critical to the PLANS design. However certain fundamental characteristics are required of each sensor type, as described in this report.

For test and evaluation purposes DREO built an

exploratory development model (XDM) PLANS, using a particular set of appropriate sensors. These consist of a Lear Siegler gyro unit (from the Lear Siegler VNAS), a Magnavox MX1107 dual channel Transit receiver, upgraded to include a single channel C/A code GPS card, a Marinex two axis gymballed magnetic fluxgate sensor (magnetic compass 900111), a Setra high output pressure transducer model 205-2 (as a baroaltimeter to provide height) and the vehicle odometer pickoff from the Lear Siegler VNAS. The interfacing and data flow from these sensors is described in this report. Although these units have been shown to be capable of meeting the system functional requirements, for the advanced development model (ADM), which should be built by early 1990, equivalent or better sensors may be substituted. This could of course require a corresponding interface change, and possibly some minor integration software changes. In the case of the keypad and displays, the XDM hardware is definitely not capable of meeting the ADM requirement, so this at least must be replaced.

The PLANS XDM processor is based on the Motorola 68000 microprocessor. It is equipped with over 600K of memory and various interface modules, as described more fully in this report.

The PLANS software is written in the high level "C" language. This software is modular and hierarchical, with seven major tasks. These are the navigation task, the Kalman filter task, the control/display unit task, the keypad unit task, the data collection task, the serial port listener task, and the data logger task.

This report provides an overview of the PLANS software structure with an overall dataflow diagram showing how the seven major tasks are interrelated. More detailed flow diagrams are also given showing the general work cycle of each of these tasks.

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1 BACKGROUND

The Canadian Forces Mobile Command has had a longstanding requirement for an Arctic navigation system. Various factors combine to make Arctic navigation very difficult, such as the lack of recognizable land features, frequent poor visibility, a weak and fluctuating horizontal magnetic field component (effecting magnetic compasses), an absence of radio navigation aid signals, and a low horizontal earth rate (effecting the accuracy of gyrocompasses at high latitudes). These difficulties, together with the grave danger associated with being lost in such a hostile environment, lead to a requirement for an automatic, all-weather Arctic navigation system. In December 1982 DLAEEM 3-2 therefore tasked DREO with the development of a Primary Land Arctic Navigation System (PLANS) to meet this requirement.

A preliminary integrated system design was proposed by DREO in 1983, using a gyrocompass, the vehicle odometer, and a Transit receiver. Originally a method was proposed to obtain heading from differential Transit measurements (AZTRANS) (which also required the use of two inclinometers), but this was found to be technically impractical by the receiver manufacturer and was finally abandoned in late 1984. By this time an alternate solution had been developed at DREO, which uses an analytic method of obtaining heading information from conventional Transit position fixes. The inclinometers were then eliminated and the large gimballed gyrocompass was replaced with a smaller directional gyro unit based on one strapdown tuned rotor gyro and one rate gyro. This newer gyro unit can gyrocompass when stationary to initialise its heading, after which it operates as a directional gyro.

Full simulation software for a 7 state Kalman filter based system was developed on a general purpose minicomputer (LSI 11/23) and was running well by early 1984. By the end of 1984 this had been transferred to a 68000 microprocessor based real time system, with all necessary sensors and interfaces, to create the PLANS Experimental Development Model (XDM), version 1.

In early 1985 a magnetic heading sensor was added to augment the gyro unit and the necessary magnetic compensation software was developed. The PLANS Kalman filter was expanded to include a magnetic heading error state and magnetic measurements. Later in 1985 this PLANS XDM was field proven at DREO on an M113 armoured personnel carrier (APC). In 1986 formal field trials were held in Petawawa using an M577 Command Post vehicle, to test the operability as well as the position accuracy of PLANS. This resulted in the reports of references 2.1.3 and 2.1.4, which verified the operability and performance accuracy of the PLANS XDM, and lead to some recommendations for changes to the displays

and operator interaction routines.

Also in 1986 the Transit receiver was upgraded to add GPS capability and the system integration software was again expanded to process GPS position measurements in the Kalman filter. In February 1987 an Arctic field trial was held in Iqaluit (Frobisher Bay), which proved the cold weather, high latitude performance of the PLANS XDM.

In 1988 an RFP was prepared to have an advanced development model (ADM) built. This ADM is expected to be delivered in early 1990. Money has been allocated for a limited purchase of 4 more units for immediate use.

2 APPLICABLE DOCUMENTS

2.1 PLANS System References

2.1.1- Project Tasking - Development of a Primary Land Arctic Navigation System 6 page memo, 10055-79-017 (DLAEEM 4), 17 November 1982

2.1.2- "Design of an Optimally Integrated Primary Land Arctic Navigation System (PLANS), Volume I, System Design", DREO Report No. 946, J. C. McMillan, DREO, Sept. 1986.

2.1.3- "Primary Land Navigation System", User Trial Report, Maj. Schuter, Oct. 1986.

2.1.4- "PLANS-A System Accuracy", Technical Evaluation, J.C. McMillan, Nov. 1986.

2.1.5- "PLANS Users Guide", a brief guide to XDM operation, in the form of a file on the DREO ED VAX.

2.1.6- "An Integrated System for Land Navigation", J.C. McMillan, Annual Technical Meeting of the Institute of Navigation, Jan. 1987, Annaheim, reprinted in NAVIGATION: Journal of The institute of Navigation, Vol. 34, No.1, Spring 1987.

2.1.7- Iqaluit Field Trial Report, in progress.

2.1.8- "An Integrated Land Navigation System", Proceedings of the Position Location and Navigation Symposium, Nov. 1988.

2.1.9- "An Integrated System for Land Navigation", AGARDograph GCP/AG 314, on Analysis, Design and Synthesis Methods for Guidance and Control Systems, editor: C.T. Leondes.

2.2 PLANS Sensor References

2.2.1- "The Transit Navigation Satellite System", Thomas A. Stansell, Magnavox, R-5933/October, 1978, USA

2.2.2- SNA 1002B Dual Channel Satellite Navigation Antenna with SAW Filter Intech, Inc. 2 page description and specification. distributed by Bytown Marine Ltd.

2.2.3- Setra Systems Inc., Model 205-2 Pressure Transducer specification sheet

2.2.4- Marinex, Compass Sensor Unit Type 900111, Jan. 1981

2.2.5- Marinex, General description, 6 pages.

2.2.6- Humphrey, specifications and drawings for the FD31-0101-1 three axis magnetometer.

2.2.7- Lear Siegler Vehicle Reference Unit: 2 page advertisement, plus written material from a short operators course.

2.2.8- Proceedings of the IEEE, Special Issue on Global Navigation Systems, Oct. 1983

2.2.9- Magnavox Report R-5871E "Installation Manual, MX1107 Dual Channel Satellite Navigator", Jan. 1982.

2.3 Interface References

2.3.1- DREO Technical Note No. 85/28, Development of a Multiple Port Serial Interface Module for PLANS, Marc Dion, DREO, 1985.

2.3.2- DREO Technical Note No. 86/21 (preliminary), Development of a General Purpose Interface Module for PLANS, Marc Dion, DREO, 1986.

2.3.3- Motorola, MVME600 Analog Input Module, Sept. 1983

2.3.4- Two page brief I/O description of Speed-Log (Lear Siegler)

2.3.5- Lear Siegler Vehicle Reference Unit: 6 page brief description of the communication protocol via the RS422A interface

2.3.6- Debounce circuit schematic for MassTech Yellow Jacket and for Forward/Reverse micro-switch

2.3.7- Analog Module board I/O pinout

2.4 Processor References

2.4.1- Motorola, MVE 110-1, VMEmodule Monoboard Microcomputer Users Manual, Mar. 1983

2.4.2- 68000 memory map as configured for PLANS, 1 page

2.4.3- Motorola, MVME210 RAM/ROM/EPROM Memory Module Users Manual, Aug. 1983

2.4.4- Motorola, MVME200/201, 64K/256K Byte Dynamic Memory Module Users Manual, Aug. 1983

2.4.5- Sky Computers Inc., Fast Floating Point Processor: System Integration Manual, Sept. 1983

2.4.6- Descriptive literature on computer files: READ.ME;1 and FFP350.DOCK;1

2.5 Software References

2.5.1- A listing of software segment names is given in file name: prgm.def

2.5.2- DREO PLANS source code listings

2.5.3- PLANS Data Flow Diagrams

3 SYSTEM DEFINITION

The Primary Land Arctic Navigation System (PLANS) is a land vehicle mounted, optimally integrated, multisensor navigation system designed and prototyped at the Defence Research Establishment Ottawa, for use by the Canadian Forces in the arctic. References 2.1.2 and 2.1.6 of section 2.1 describe the difficulties of this task, and the means by which PLANS overcomes these difficulties. The accuracy and functional performance of this Experimental Development Model (XDM) have been verified through field trials in Ottawa, Petawawa and Iqaluit (Frobisher Bay), as reported in references 2.1.4 and 2.1.7.

3.1 General Description

PLANS is a multisensor navigation system employing an eight state Kalman filter (described in reference 2.1.8) to provide optimal estimates of the vehicle position, speed and heading. The primary navigation information is obtained by simply dead reckoning the heading and speed information that is continuously available from the gyrocompass / directional gyro (a Lear Siegler Vehicle Reference Unit in the PLANS XDM) and an odometer pickoff. (The Lear Siegler VRU can gyrocompass when the vehicle is not moving to provide an initial heading estimate, after which it reverts to directional gyro (DG) mode.) These are autonomous sensors (not relying on any external transmissions) which together provide continuous position and velocity. All other sensor information is used by the Kalman filter to form corrections to this dead reckoned position and velocity.

Absolute positional information is obtained at aperiodic intervals from the Transit satellite system and is available from the Global Positioning System (GPS) whenever the GPS satellite coverage is adequate. Both of these come from a Magnavox MX1107 in the PLANS XDM which has a two channel Transit receiver and a single channel C/A code GPS receiver. Since Transit requires height information, a baroaltimeter is combined by the Kalman filter with computer generated data from an elevation map to determine an optimal height estimate.

The MX1107 is completely controlled by the PLANS processor. To do this a keypad emulator was developed, allowing the MX1107 keypad and display to be removed. PLANS itself is controlled via a 4x5 keypad, with an 8-line by 20-character display.

A magnetometer provides magnetic heading, from which a true heading estimate is formed by using a computer generated

geomagnetic field model and a magnetic calibration function. The Kalman filter uses this to aid the directional gyro heading. Thus by using the dead reckoning (gyro and speed) along with whatever aiding sensors are available, an optimal estimate of the present vehicle position and velocity is always available.

Sensor error detection and rejection routines are also implemented to protect the integrated solution from bad measurements.

3.2 Functional Subunits

The PLANS XDM consists of four main functional subunits, as shown in block diagram form in figure 1.

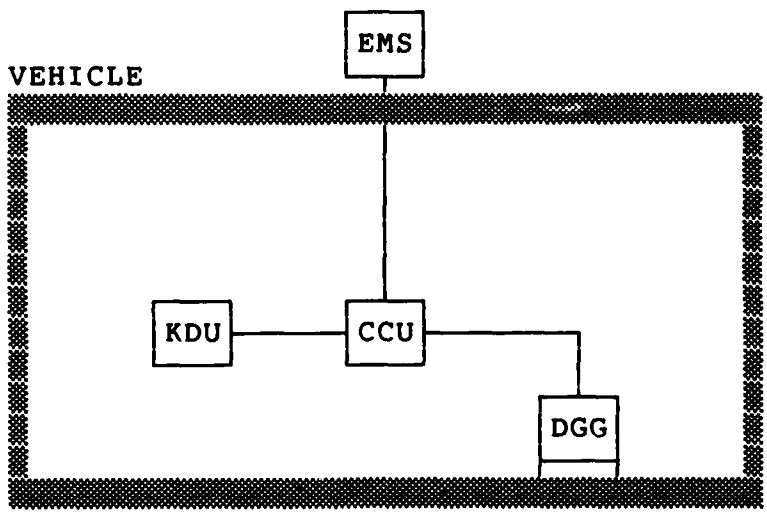

Figure 1. Functional Subunits

These blocks represent the following:

1- the Central Control Unit (CCU) housing the system electronics, (satellite receivers, computer and interfaces) which can be mounted (shock mounted if necessary) anywhere in the vehicle.

2- the Directional Gyro/Gyrocompass unit (DGG), which must be hard mounted to the vehicle, preferably near the centre of gravity.

3- the Externally Mounted Sensors (EMS), consisting of a

Transit antenna, GPS antenna and magnetometer.

4- the Keypad/Display Unit (KDU) is presently a standard video terminal (in the ADM it is meant to be hand-held and connected to the CCU by cable).

3.2.1 Central Control Unit (CCU)

This unit contains the interfaces to collect and digitise the measurements plus the processor and memory to store and run the software that performs the navigation and waypointing algorithms, the data prefiltering and Kalman filtering algorithms, the failure detection and error rejection algorithms, and the operator interaction and display driving algorithms.

This unit also contains some of the navigation sensors: namely the baroaltimeter and the MX1107-R Transit/GPS satellite receiver cards, with the necessary oscillators. The baroaltimeter requirements are described in section 5.3 below, and the Transit and GPS satellite receivers are described in section 5.5.

The CCU also contains power supplies to power everything in the CCU. The CCU takes input from the keypad/display unit (KDU), the directional gyro/gyrocompass unit (DGG) and the externally mounted magnetometer and satellite antennas. The CCU provides serial output to the remote displays and the KDU. The CCU provides power to the DGG, the KDU, the magnetometer and the remote displays. The CCU obtains its power from the vehicle batteries. Figure 2 of section 3.3 below shows the basic contents of the CCU and their relationships to other PLANS components.

3.2.2 Directional Gyro/Gyrocompass Unit (DGG)

This unit performs the physical measurements necessary to provide the required real time inertial heading and attitude data for processing by the CCU. This unit contains the necessary gyros, accelerometers, electronics and processor(s) to perform true north seeking (gyrocompassing) when the vehicle is stationary, and to thereafter dynamically maintain the vehicle's heading, pitch and roll. The DGG communicates with the CCU via an RS422 serial line. Power is supplied by the CCU. A more detailed description of the DGG requirements is given in section 5.1 below.

3.2.3 Keypad/Display Unit (KDU)

The keypad/display unit is to be a hand-held or lap held unit for providing the equipment-to-user interface to give the operator the ability to enter and extract the information

required to meet the mission requirements. The information shown on each display shall be specific to that display's function. This XDM KDU provides the necessary information, but on a standard video terminal. These displays are described in more detail in section 3.5 below.

3.2.4 Externally Mounted Sensors

The MX1107 has two antennas (one for the C/A code GPS and one for the two Transit channels) that must be mounted on the top of the vehicle in unobstructed locations. The magnetometer should also be mounted external to the vehicle in a location where the disturbance of the earth's magnetic field by the vehicle and its contents is minimal (at least .2 metres from any significant amount of high permeability material such as steel or iron). The XDM magnetometer is described in section 5.4 below.

3.3 Interface Definition

The PLANS is a multisensor system and as such the CCU requires interfacing between the processor and many different sensors. Figure 2 identifies the major XDM components, their interfacing and interconnections. As can be seen from this figure, the processor communicates with the various interface modules via a data bus, and a breakout panel is used to connect these various I/O modules with the sensors.

3.3.1 Interfaces to Vehicle Supplied Units

The PLANS unit is required to interface to the vehicle power system (see QSTAG 307) and the vehicle odometer. The Lear Siegler odometer pickoff requires a pulse counting circuit, which is part of the general interface card, described briefly below and more fully in reference 2.3.2.

3.3.2 Interfaces to PLANS Units External to the Central Unit

System components external to the PLANS XDM central unit, but part of the PLANS system and to which interfacing is required are: two remote displays (LCDs); two antennas (Transit and GPS); the magnetometer; the directional gyro/gyrocompass (Lear Siegler VRU); and the main keypad/display unit (KDU). There must also be a power connection to the vehicle's electrical system.

The Marinex flux-gate magnetometer has three output lines, requiring two differential A/D converters. The two voltages are proportional to the sine and cosine of the measured magnetic heading, as described in references 2.2.4 and 2.2.5. If

this were replaced by a 3-axis strapdown unit, such as the Humphry FD31-0101-1 now being tested on the XDM, there would be 3 voltage outputs.

The Lear Siegler VRU requires a single RS422 serial interface, operating at 9600 baud, which serves to control the VRU and extract the necessary data from the VRU.

The KDU requires a clocked serial line for the custom LCD display and a parallel matrix interface for the keypad. These are described in more detail in reference 2.3.2.

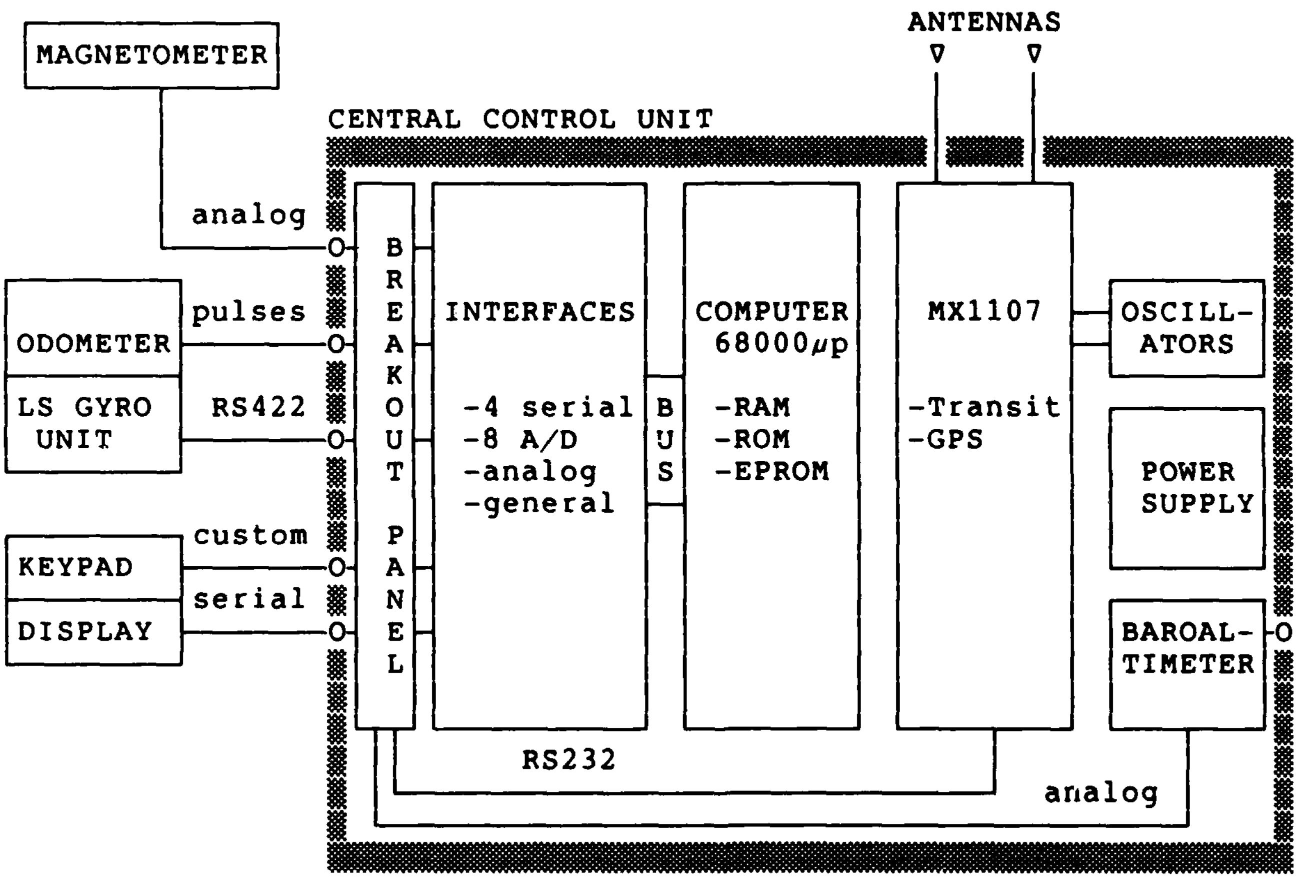

Figure 2. System Block Diagram

3.3.3 Interfaces to PLANS Units Internal to the Central Unit

The Central Control Unit contains two satellite receivers and a baroaltimeter which require interfaces. The MX1107 Transit/GPS receiver has an RS232 serial interface (the "remote computer interface" described in reference 2.2.9) operated at

2400 baud. The Setra baroaltimeter has 0 to +5 VDC analog output.

3.3.4 Quad Serial Port Interface

This module was designed and built at DREO. It contains four independent serial channels using either the RS-232C or the RS-422A standard. The baud-rate is switch-selectable for each channel and the data format is selected under software control. One channel is used for data logging, one to interface with the gyrocompass and two to interface with the satellite receiver. The ports are configured as follow:

#	USAGE	FORMAT	BAUD	DATA FORMAT
1	Spare or data logging	RS-232C		
2	Lear-Siegler gyrocompass	RS-422A	9600	8-bit, odd-parity
3	MX-1107 remote interface	RS-232C	2400	8-bit, no-parity
4	MX-1107 external interface	RS-232C	600	8-bit, no-parity

3.3.5 Analog Input Module

This module, manufactured by Motorola (VMEmodule #MVME600), provides a complete multi-channel, 12-bit, analog data acquisition. It is configured to provide 8 differential channels. One channel is used to read the baroaltimeter and two channels used to read the magnetometer outputs.

3.3.6 Analog Module

The only function of this module is to filter-out noise from some input signal lines. Though it plugs into the I/O Channel, all the data lines in and out are accessed through the front connector.

3.3.7 General Purpose Interface

This module was designed and built at DREO. It contains all the necessary logic to interface with a speed-log unit, a 20-key keypad, three LCD displays, a Magnavox receiver and provides 256 bytes of non-volatile RAM.

The Arma-Brown gyrocompass (an original candidate for PLANS heading sensor but later used only as test equipment) is interfaced through a parallel port of 16 data and one control lines. An external synchro-to-digital converter is required. This gyrocompass is no longer used and therefore this interface is obsolete.

The odometer outputs two pulse trains corresponding to the distance travelled. This module incorporates a 24-bit counter and the necessary latches to extract the direction of travelling.

The keypad consists of an array of SPST switches arranged in 4 rows of 5 columns. This module provides the necessary logic to scan and debounce the switches.

The MX-1107 satellite receiver is operated through a 16-key keypad which produces a debounced, active low TTL output. This module incorporates the appropriate logic to properly emulate that keypad.

The XDM originally incorporated a main LCD display and two remote LCD displays (later replaced by a standard video terminal). The data is sent to all the displays through a common serial link consisting of four data and control lines. Each display has the necessary logic to demultiplex the data received and to control the LCD drivers. This module incorporates the logic to convert the data into serial form, generates a synchronising clock and the handshake signals.

This module also provides 256 byte of non-volatile RAM which are no longer used and had been replaced by JEDEC-compatible ICs now available.

3.3.8 Dual Channel Serial Port

This module, manufactured by Motorola (VMEmodule #MVME400), provides two independent full RS-232C serial input/output ports. It is used to connect to a host and to a data logging recorder during development.

3.3.9 Console interface

This is the only interface not accessed through the I/O Channel. It is an RS-232C serial interface used to connect a console terminal. This port is used during development and testing only. It is located on the CPU module (MVME110).

3.4 Component Sources

3.4.1 Software

The real time PLANS software, together with some development and test software, was developed entirely at DREO. Laboratory development level documentation has been produced, mostly in the form of comments within the code. This will include task descriptions and module descriptions. The source code shall be C-language Release 2.2, March 1983, Whitesmiths Ltd. This software is described further in section 6 below.

3.4.2 Commercial Hardware

All hardware used in the PLANS XDM is commercially available at the board level or above except for the General Purpose Interface (GPI) (described in reference 2.3.2), the Quad Serial Port (QSP) (described in reference 2.3.1), and the Analog board. The design details of these non-commercial subassemblies will be provided with full theory of operation descriptions so that functionally equivalent hardware may be designed or purchased and integrated into the system.

3.5 Keypad and Displays

One keypad and three displays are required. They are identified as the main display, the remote commander display, and the remote driver display (the two remote displays are almost equivalent, so common hardware can be used). Custom LCDs were developed for the XDM main and remote displays, as described in reference 2.1.2, but they feature geographic rather than grid coordinates, and heading in degrees from true north rather than mils from grid north. The main LCD display has been abandoned for reliability reasons, and is being emulated on the XDM by a VT100.

3.5.1 Main Display Unit

The XDM main display unit contains a display and keypad with all indicators and controls required for system operation. This display uses 8 rows of 20 characters, and is visible under all lighting conditions within the vehicle. The layout for this display is shown in figure 3 below, and described in reference 2.1.2. The XDM keypad has twenty keys arranged as a four row by five column matrix as shown in figure 4 below. The main display unit shall be either hand held or lap held, remotely connected via cable to the CCU. This display shall be used by both the commander and the navigator during the mission. The display unit

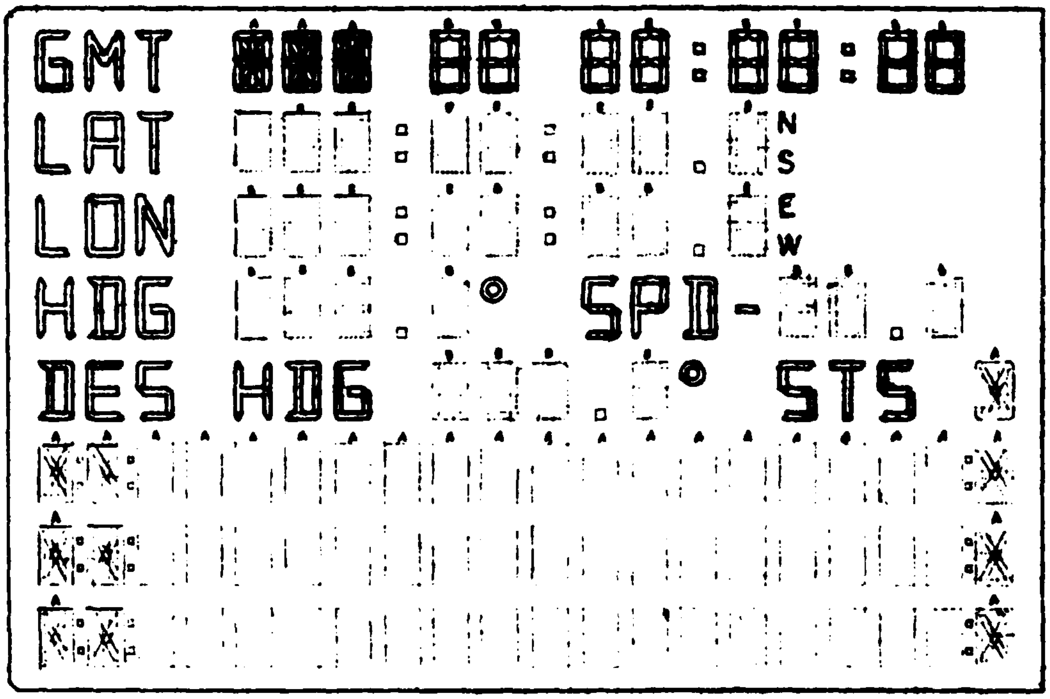

Figure 3. Main Display Layout

shall be portable to allow unrestrained access and use within the vehicle.

1	2	3	MODE	CLEAR
4	5	6	WAYPT	LIST
7	8	9	<——	——>
+/-	0	.	HELP	ENTER

Figure 4. Keypad Layout

3.5.2 Remote Commander Display

The XDM commander display is mounted on a pivoting bracket, inside the vehicle just below the front of the roof hatch of the M577 vehicle. This placement allows the displayed position and heading information to be visible to the commander while he is in an external observation position, standing partly out of the vehicle. Simultaneous viewing of this display and the main display are possible. (Note: The placement of the display will be different for the BV-206 over snow articulated vehicle.) This display does not contain any controls required for system operation.

3.5.3 Remote Driver Display

The driver display is mounted on a pivoting bracket in front of the drivers position. It is mounted and dedicated for the driver's use only, and can be pivoted so that its displayed data is visible to the driver in either a "sitting up" or "sitting down" position (ie. while driving with an open hatch or closed hatch). This is a passive display, without any controls required for system operation. (It does however have controls for display operations such as brightness and heading display format).

3.5.4 Displayed Information

The XDM system is capable of continuously displaying vehicle geodetic position in the form of WGS-84 latitude and longitude, in degrees, minutes, seconds and tenths of seconds, as well as UTM (Universal Transverse Mercator) north and east coordinates in tens of metres (to nearest 10 metres) including the zone number. It also continuously displays speed in kilometres/hour (to nearest .1 km/hr) and heading in degrees (to nearest .1 degree), as well as position accuracy information, the absolute time (Greenwich Mean Time) in hours, minutes and seconds (to nearest second). The main display continuously displays a status value, which provides a quantitative indication of the expected accuracy of the PLANS position estimate. It also displays specified waypointing information.

3.5.5 Tabular Summary of Displayed Information

symbology:
- X information always visible on display
- S information selectable from Navigators keypad
- T toggled (selectable) from Drivers (Dr.) or Commanders (Com.) display
- \- not displayed

Vehicle Information	Main	Dr.	Com.
Filtered (1) Latitude and Longitude (2)	X	X	X
Filtered Northings & Eastings (3)	S	S	S
Filtered Current Heading	X	X	X
Filtered Course Deviation a) numerical display	-	T	T
b) bow-tie display	-	X	X
Filtered Current Speed [note (4) for *]	X	*	-
GMT	X	-	-
Dead Reckoning latitude, longitude, heading & speed	S	-	-
Magnetic Heading, Declination and Field Strength	S	-	-
Transit Fix data: lat., long., elevation, & time (5)	S	-	-
Vehicle Heading estimates (Gyro, Flux-gate and GPS)	S	-	-

Altitude estimates: Map, Baro., GPS and Filtered	S	-	-
Position estimates: Transit, GPS, DR (6)	S	-	-
Keypad response to input	X	-	-
Status number (figure of quality) (7)	X	-	-
System Status Information	S	-	-
Help Function	S	-	-
Waypoint Information (for any wpt., maximum of 6)			
Latitude and Longitude	S	-	-
Northings & Eastings	S	-	-
Desired Heading (bearing of selected waypoint)	X	T	T
Range to any waypoint	S	-	-

Note 1 : Filtered indicates that the data displayed is an output of the Kalman filtering process

Note 2 : all latitudes and longitudes are in WGS-84 coordinates.

Note 3 : all northings and eastings are in UTM (Universal Transverse Mercator) coordinates (based on the Clarke 1866 spheroid and NAD 1927 datum).

Note 4 : * A filtered speed is not seen by the Driver, however, the APC speedometer shall be visible to the Driver.

Note 5 : Position refers to the vehicle, Elevation refers to maximum elevation of the satellite above the horizon.

Note 6 : Data from these sensors has been dead reckoned to the current time. DR is the estimated position dead reckoned from the initial position in WGS-84 coordinates.

Note 7 : the status is a Number from 0 to 9, and is a function of the position error covariance from the Kalman filter.

3.6 Operating Procedures

Reference 2.1.5 gives a more detailed description of the operating procedure. The PLANS XDM is menu driven, with a "HELP" utility, to minimise the number of commands that the operator must remember. It is intended that reading the keypad keys and the displayed prompts will be sufficient to enable anyone familiar with the basic concepts of navigation to operate this system.

3.6.1 Initialisation Procedures

The PLANS XDM is ready to start keypad initialisation immediately after power up. Initialisation, including gyrocompassing, takes no longer than 20 minutes, after which dynamic navigation commences.

3.6.2 Adjustments

No other equipment adjustments after the initial installation are required to operate the system. There will be the facility to perform a calibration of the magnetometer, but this special feature is not intended for routine use. It will be recommended that this be done only when the vehicle has been reconfigured, moved a great distance from its last calibration point, or over a year has passed since the last calibration.

3.6.3 Special Operational Requirements

No special operational considerations are required to enter the shutdown or power off mode.

4 SYSTEM FUNCTIONAL CHARACTERISTICS

4.1 System Accuracy

The system accuracy requirement is specified in QSTAG 615 Navigation and Position Fixing Accuracies, for patrols at extreme latitudes. The XDM accuracy, without GPS, has been determined by field trials in Petawawa September 1986 and in Iqaluit (Frobisher Bay) in February 1987 and has been reported in reference 2.1.4.

4.1.1 Positioning Accuracy

Positioning accuracy is better than 312 meters 95% (150 meters CEP), even when GPS is not available. (It is desirable that positioning accuracy be better than 100 meters 95%, which can currently only be attained during periods of good GPS coverage or under smooth hard road conditions.)

4.1.2 Heading Accuracy

Heading accuracy is better than 4 degrees 95%. (It is desirable that heading accuracy be better than 2 degrees 95%, which can currently only be achieved at low to medium latitudes.)

4.1.3 Time Accuracy

Displayed time is accurate to at least 1 second.

4.2 Resolution of Displayed Data

4.2.1 Position

On all three displays the vehicles geodetic position, (WGS-84) is continuously displayed in full latitude and longitude, in degrees, minutes, seconds and fractions of a second, to a resolution of 0.1 second in each coordinate direction. The UTM northings and eastings are also continuously displayed on the Main Display to a resolution of 10 metres.

4.2.2 Heading

The Main display continuously displays the vehicle's true and desired heading in degrees, to a resolution of 0.1 degree (clockwise from true north to the vehicle lubber line). The Drivers and Commanders displays have a switch to select for display either the actual heading or the difference between the actual and desired heading, in degrees, to a resolution of 0.1

degree.

4.2.3 Steering Indicator

The Drivers and Commanders displays continuously display an analog representation of the difference between the actual and desired heading, in the form of a "heading to steer" indicator, showing the direction and magnitude of the desired steering correction needed to bring the vehicle onto the desired course.

4.2.4 Speed

The Main display continuously displays the vehicle's true speed in kilometres per hour, to a resolution of 0.1 km/hr.

4.2.5 Waypoint Data

The Main Display can on request display the bearing from one selected waypoint to another (the present vehicle position being a waypoint) to the nearest 0.1 degrees. This unit can also on request display the distance to travel (range) to the next waypoint to the nearest metre.

4.3 Keypad Entry

A more detailed description of the necessary sequence of inputs required to operate the PLANS XDM is given in reference 2.1.5.

4.3.1 Coordinate Entry

Position entry is accepted by the XDM in either UTM northings and eastings, in kilometres, or in WGS-84 latitude and longitude coordinates in either degrees, minutes and seconds, or in degrees and minutes (with decimal minutes) or in degrees (with decimal degrees). The resolution accepted is equivalent of 0.1 arcsecond (about 3. meters) in each coordinate direction.

4.3.2 Way Point Entry

The XDM allows keypad entry of up to six way point positions in either UTM northings and eastings or in WGS-84 latitude and longitude, as described in 4.3.1 above, to a resolution of 0.1 arcsecond.

4.3.3 Heading Resolution

Keypad entry of the vehicle's heading is accepted to the

nearest 0.1 degree (with respect to the vehicle lubber line and true north).

4.3.4 Input Confirmation

All keypad entries are echoed to the user on the main display to provide positive feedback and confirmation of input.

4.4 Restrictions

4.4.1 Operational Interference

The presence of the PLANS does not interfere with the proper operation of the vehicle or the personnel.

4.4.2 Active Devices

The system does not use any devices resulting in detectable electromagnetic, optical, or acoustical transmissions from the vehicle.

4.4.3 Power Control

The PLANS power source can be electrically applied or removed without affecting any other vehicle systems.

4.4.4 Power Interruption

After interruption of power PLANS is capable of continuing its operation by simply reinitialising through the standard startup procedure. The last best values before power interruption are used as default values at initialisation.

5 SENSOR PERFORMANCE CHARACTERISTICS

The following paragraphs specify the operational and performance requirements for the PLANS sensors. Note that the accuracy figures are given with a desired confidence level of one standard deviation (approx. 68%).

The primary sensors are the Gyrocompass and the satellite receivers, and for these the particular sensors chosen by DREO are identified. These identified units have been shown to be capable of meeting the minimum system performance requirement, but should not be considered to be the mandatory selection.

5.1 Directional Gyro/Gyrocompass

The gyro unit shall be capable of dual mode operation: as a gyrocompass (at least in stationary vehicle mode) and as a directional gyro. It shall also provide status and dynamic pitch and roll attitude. It shall be capable of being controlled by the PLANS computer (preferably over an RS422 or RS232 serial line), with no direct operator interaction. It shall be capable of gyrocompassing in the target vehicle while it is idling, at latitudes up to at least 80. degrees (preferably 83. degrees). The unit selected by DREO for the PLANS XDM is the Lear Siegler Vehicle Reference Unit (VRU), which is the heading/attitude sensor for their "VNAS" (Vehicle Navigation Aids System), and is described very briefly in references 2.2.7 and 2.3.5. This unit has a settle time of 4.5 minutes, but several settles must be averaged to obtain the required gyrocompassing accuracy at high latitudes.

5.1.1 Directional Gyro Mode Accuracy

The heading drift rate on the Lear Siegler VRU has been measured to be less than 1. degree per hour, one sigma under the specified operating conditions, and normally less than .5 degrees per hour. The pitch and roll accuracy were less precisely measured, but should be better than 2. degrees each (one sigma).

5.1.2 Gyrocompass Mode Accuracy

The one sigma gyrocompassing error in degrees shall be less than .5 secant(latitude) over the area of operation (between 60°W and 140°W longitude and between 60°N and 84.5°N latitude). This can be accomplished by multiple realignment if necessary, (using the average settled heading value to adjust the final settled value) but must be achieved in less than 20 minutes, It

was found at DREO that 4 settles on the Lear Siegler VRU accomplished this.

5.1.3 Settling Time

The settling time must be less than 20 minutes from power-on. Settling time is defined as the time required for the gyro unit to reach the specified gyrocompass heading accuracy, from a cold start.

5.1.4 Rate Limits

The gyro unit must be able to accurately track the expected maximum angular rate of the host vehicle (about 2. radians per second). The heading and attitude output must be available at least once per second (preferably at a 10. Hz. rate).

5.1.5 Weight/ Volume/ Power

The Lear Siegler VRU weighs about 4.5 kg. (10 lbs.), has a volume of about 4662 cubic centimetres (284.5 $in.^3$) and consumes about 58 watts of power.

5.1.6 Reliability

MTBF data is not presently available for the VRU.

5.2 Speed Sensor

This device is an odometer pickoff type, converting odometer cable rotation into pulses. The PLANS XDM uses the Lear Siegler Distance Measurement Unit (DMU), which is also a part of the VNAS system. At present the standard equipment on our M577 and BV206 vehicles includes only one odometer cable, on one track. (It would be beneficial to have one on each vehicle track.)

5.2.1 Resolution

This DMU speed sensor provides a resolution of about 355 pulses per metre on the M577 vehicle odometer cable (or any other vehicle odometer with similar revolutions per metre). This results in a .01 km/hr speed resolution at a 1 Hz sample rate.

5.2.2 Vehicle Direction

The speed sensor output indicates forward or reverse vehicle motion.

5.2.3 Weight/ Volume/ Power

The Lear Siegler DMU weighs about 0.82 kg., has a volume of about 1367. cc, and consumes no power.

5.3 Baroaltimeter

The PLANS XDM uses a Setra high output pressure transducer, model 205-2, as a barometric sensor. This is a small, light weight, low power sensor, which is sufficiently rugged and sensitive. This unit is described in more detail in reference 2.2.3. Since this sensor is to be mounted in or on the central control unit, which will be mounted inside the vehicle, the environmental conditions are not as extreme as with the externally mounted equipment.

5.3.1 Pressure Range

The linear pressure range (gage and absolute) is from 0 to 25 psi. to completely cover the expected barometric range. (Linear is defined as less than 1% deviation.) The region of primary interest is from 10 to 20 psi.

5.3.2 Accuracy

According to the manufacturers specifications, the output is accurate to within 1.9 mBar at constant temperature, the hysteresis does not exceed 0.0275 psi. and the acceleration response is less than 3.5 mBar/g, pressure port axis only.

5.3.3 Weight/ Volume/ Power

The Setra 205-2 weighs about 113 grams, and occupies about 25 cc. of volume. The required excitation is 15 to 30VDC. Power consumption is less than about 0.2 watts. The output is DC voltage. The output impedance is less than 10 Ohms.

5.4 Magnetometer

The PLANS XDM was originally built with a Marinex compass sensor unit 900111, which is a 2-axis, gimballed marine magnetometer, described in references 2.2.4 and 2.2.5. The XDM is being modified to use a 3-axis strapdown unit (a Humphrey FD31-0101-1) described in reference 2.2.6.

5.4.1 Signal Representation

The gimballed magnetometer is a 2-axis unit, which measures field strength in the locally horizontal frame (with one axis being the projection of the vehicle centreline into the horizontal plane). The 3-axis strapdown unit measures three orthogonal components in a vehicle fixed frame. The strapdown unit will require the PLANS system to have attitude information (such as provided by the Lear Siegler VRU) to project these into the locally level frame (otherwise it must be assumed to be level, with the resulting errors).

5.4.2 Static Accuracy

The magnetometer provides a one sigma static magnetic heading accuracy in degrees (after calibration to remove the vehicle's hard and soft iron effects) of better than 34000/H where H is the horizontal field strength in nano-Tesla (nT).

5.4.3 Dynamic Accuracy

The dynamic errors induced by normal vehicle motion on the gimballed unit degrades the magnetic heading accuracy by not more than a one sigma value of about 10000/H where H is the horizontal field strength in nano-Tesla (nT).

5.4.4 Weight/ Volume/ Power

The Humphry unit weighs about 1.0 kilogram and occupies about 1210 cc volume. The Marinex unit consumes about 1.0 watt, but would also require heating, whereas the Humphrey unit consumes about 4.5 watts and does not require heating.

5.4.5 Environmental

Since this unit must be mounted external to the vehicle, it must be very rugged and must operate at very low temperatures (-55°C). In order for the Marinex unit to function during the Iqaluit trials, warm air from the vehicle was directed to an enclosure around the unit.

5.5 Satellite Receiver/Processor

The PLANS XDM uses the Magnavox MX1107R with the GPS upgrade (see reference 2.2.9). This has a two channel Transit receiver and a C/A code GPS receiver. For the XDM the MX1107 electronics chassis has been removed from its housing and mounted within the PLANS CCU. The MX1107 video display, keypad, battery and housing have been "discarded".

5.5.1 Receiver Requirements

The receiver must have the capability to select and track the best one of several coincident (interfering) satellite passes. (This is required because at higher latitudes the number of coincident passes increases resulting in more interference.) The receiver must be capable of complete remote control by the PLANS computer (preferably over an RS232 or similar serial interface), so that no direct operator interaction is required with the receiver. Since the antennas must be mounted external to the vehicle they must be sufficiently rugged and must operate at very low temperatures.

5.5.2 Output Data Requirements

The receiver must provide the correct information necessary for PLANS to optimally integrate the Transit position fixes, and the GPS position and velocity measurements. This includes:

- -Greenwich Mean Time
- -Transit fix mark (time of fix validity)
- -Transit satellite direction of travel (N/S & E/W or rising quadrant)
- -Transit satellite maximum elevation angle
- -Transit fix validity (quality) flag
- -Transit fix Latitude and Longitude (WGS84)
- -Transit Satellite ID
- -GPS Latitude (WGS84)
- -GPS Longitude (WGS84)
- -height
- -GPS north and east velocity components
- -GPS north, east and vertical geometric dilution of precision (NDOP, EDOP and VDOP)
- -number of GPS satellites visible
- -status

The GPS data must be continuously available at a rate of at least .1 Hz.

5.5.3 Weight/ Volume/ Power

The MX1107 console, as purchased with it's yoke, case, keypad, display and batteries, (which were removed for insertion into the PLANS XDM) weighs about 38.6 kg, occupies about 64,439. cc and requires 175 watts maximum. About 45. watts are used by the MX1107 display.

5.6 Power Supplies

The XDM operates on vehicle power, which is 28 VDC. The system requires 5 VDC and ±12 VDC for its computer, satellite receiver and sensors. The gyro-compass operates from the vehicle power directly. Two DC-to-DC power-supplies are used. One provides 5 VDC at 36 Amp and the other ±12 VDC at 2 Amp.

6 PLANS SOFTWARE

6.1 System Software

The PLANS uses the VRTX operating system, a real-time operating system on a 4K PROM. VRTX is written as position independent code so it may be located anywhere in the user's address space. The VRTX executive provides an operating system kernel, in effect adding several high-level instructions which allow the user to create a multi-tasking real-time system. The VRTX system calls are grouped as follows:

- multi-tasking management (task creation / deletion / suspension / resumption / priority)

- memory management (allocation / release & partition creation / deletion)

- task communication (post / pend / accept & queued post / pend / accept)

- interrupt management (post / qpost from interrupt)

- clock support (get / set time, delay)

- character i/o (get char / put char)

A device driver is an asynchronous process that calls and is called by the Operating System. A driver performs the following functions:

- receives and services interrupts from I/O devices

- initiates I/O operations when requested by the Operating System (from a user request)

- cancels in-progress I/O operations

- performs device specific functions on power-up, timeout,etc.

In particular, device drivers are required for RS232 serial lines, A/D converters, odometer counter, keypad, LCD, non-volatile ram and the keypad emulator.

A floating point processor (FPP) is required in order to perform the matrix arithmetic in the filter. VRTX was changed to initialise the FPP and to generate appropriate calls (to the FPP if present, to software floating point package if not)

The PLANS was written in the "C" programming language. C is a general purpose programming language, originally written for the UNIX operating system, but now popular on many micro-computers. C provides the fundamental flow constructions required for well structured programs: statement grouping, decision making, looping with termination test at the top or at the bottom, and selection of one of a set of possible cases. C provides the standard data types (char, short, int, float, double, etc.) and the ability to define data sets (stuct, union). Most important, C provides pointers and the ability to do address arithmetic, a useful feature in most programs, especially micro-computers. Arguments to functions are passed by value, arrays are passed by reference. The major advantage of C is that it reflects the capabilities of current computers. Thus, C programs tend to be efficient enough that there is no compulsion to use assembly language instead. The major disadvantage is that there is no standard utility routine package defined (I/O, math, etc.) and each compiler uses slightly different names or argument lists.

6.2 Application Tasks

An application task exists for each of the major functions in the PLANS system. Figure 5 illustrates the overall software structure and shows the various tasks. The tasks and their functions are described below.

6.2.1 Data Collection Task (DCT)

The primary purpose of the Data Collection Task (DCT) is to provide an interface between the device drivers (and thus the sensor interfaces) and the application tasks which require the raw sensor data. This involves initialising the sensors and the collection of the sensor data at specified rates (DR, flux, baro, GPS) or as it becomes available (Transit). As well, DCT feeds velocity and altitude to the transit receiver and monitors the PLANS system clock (by checking it against the time at a transit fix).

DCT is essentially a time driven task. At periodic intervals, it wakes up, reads the various sensor interfaces, formats the sensor data using the appropriate data structure and sends the data to the other application tasks requiring the data. Reading the sensor data can be either through the device driver or through another task (in the case of the transit data). After

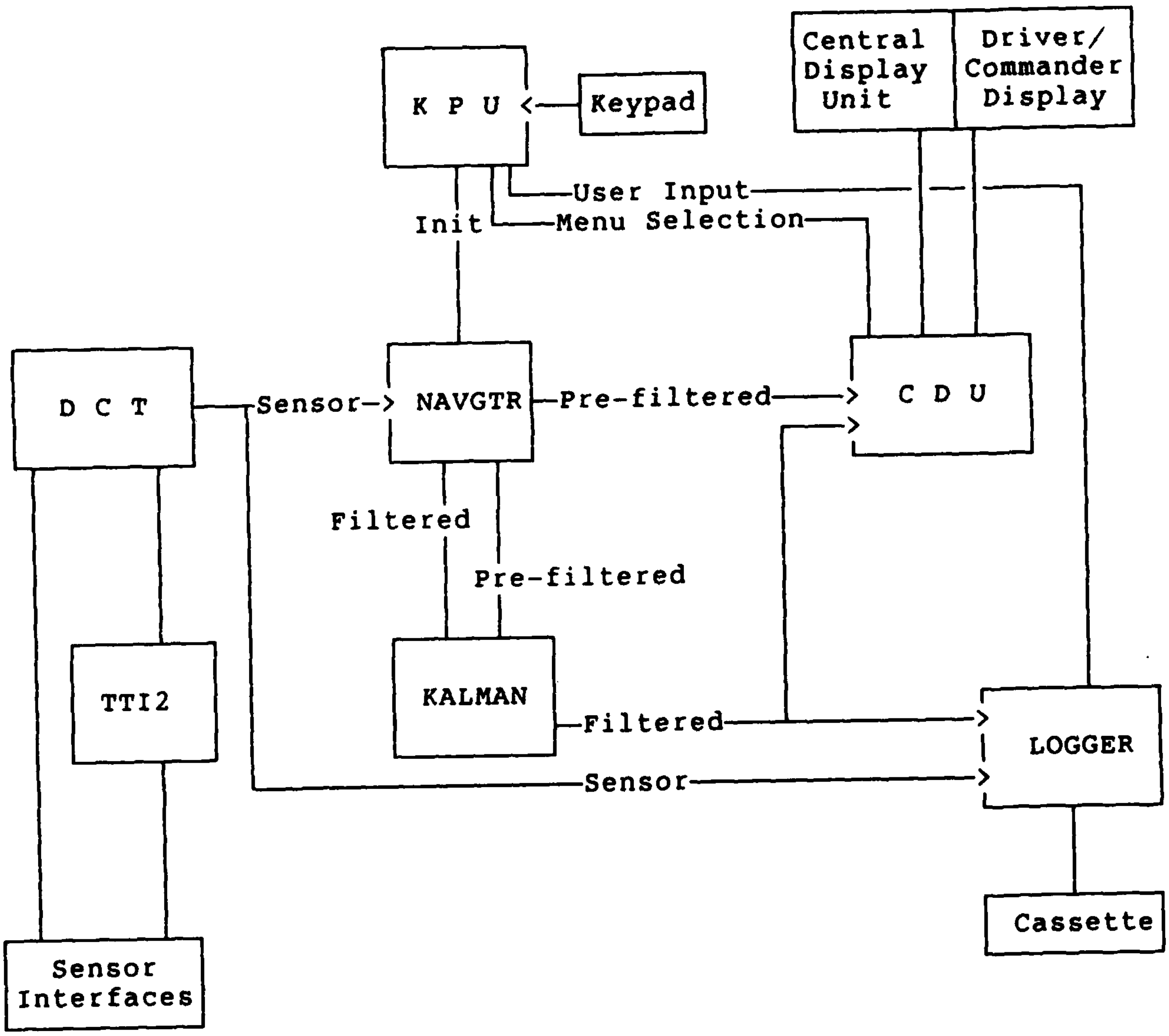

Figure 5 PLANS Task Structure

reading all the sensor data, DCT waits for the next wake-up. Figure 6 illustrates the general work cycle of the DCT.

6.2.2 Serial Port Listener (TTI2)

The VRTX executive does not provide a mechanism to perform a device driver read operation, continue program execution and check at some later time if the read has completed. This is a useful feature, especially in the case of serial I/O, where the input might not come for a long time or the output might take a long time to do. In PLANS, the transit data is received over a serial port but at indeterminate aperiodic intervals. If the DCT reads the serial port, then it is locked on the device read until transit data is received (and no other sensors can be read).

The serial port listener task (TTI2) reads the serial port connected to the transit/GPS receiver. When a read completes, the ASCII data is sent to the DCT and another read is issued. In this way, the serial line is continuously monitored for transit data and the DCT is free to collect data from the various sensors at the required rates. Figure 7 illustrates the general work cycle of the TTI2 task.

Nothing is ever as simple as it seems. The transit data is contained in two transmission blocks. The first block is sent automatically by the receiver. The second must be requested specifically. As well,both transit and GPS are received on the same serial port (GPS also requires two transmission blocks). TTI2 requests these extra blocks in order to minimise delays in processing the data.

6.2.3 Navigation Task (NAVGTR)

The navigator task (NAVGTR) provides the display task with continuous up-to-date position, velocity and status information. To do this effectively, this means that NAVGTR must perform the pre-filtering and dead-reckoning functions. Pre-filtering involves continuity and reasonableness testing of the sensor data. Dead-reckoning involves integrating heading and speed from a time T0 to time T1 and knowing the position at time T0 to find the position at time T1. Doing these functions in a separate NAVGTR task rather than the filter task allows the system to provide the user with real-time information and also to perform Kalman filtering of sensor inputs in a background mode. As well, the NAVGTR provides gyro settling/alignment information to the user. For the Lear Siegler, the system performs multiple alignments and uses the average as the initial heading.

The NAVGTR task is data-driven in the sense that it performs its functions on the data as it receives the data. It does not request data and relies on other tasks providing the data at appropriate intervals (although all data is time-stamped as it is requested by DCT). As part of the pre-filtering process, it maintains statistics on sensor data errors. Figure 8 illustrates the general work cycle of the NAVGTR task.

6.2.4 Kalman Task (KALMAN)

The purpose of the filter task (KALMAN) is to implement the Kalman filter based sensor blending algorithms. Reference 2.1.2 provides a description of the analysis and design process by which this task was developed. Some of the functions of this task are to propagate the covariance matrix and state vector from the last update to the current point in time, to form the filter measurements from the sensor data, to perform the residual tests on these measurements and to process the measurements using the Kalman update algorithm. This task also includes a prefilter, which preprocesses some of the measurements to apply corrections or suppress noise. For example, since the baroaltimeter could have a large bias error if used alone, an elevation map is used to bound this error. As well, the fluxgate can have a large error (since the magnetic north is not the north pole) so a geomagnetic field model is used to correct this error. Some prefilter averaging is also applied to the magnetic measurements.

The KALMAN task, like the NAVGTR task, is data driven. It processes the data as it is received and relies on other tasks to perform the timing functions. Since the NAVGTR task performs the dead-reckoning, it is not critical that the KALMAN task perform the filtering functions in less than the dead-reckoning time interval (although the smaller the delay, the better the real-time accuracy). Figure 9 illustrates the general work cycle of the KALMAN task.

6.2.5 Keypad Task (KPU)

The Keypad Task (KPU) allows the user to enter information to the PLANS system through the keypad. The PLANS system might need this information for system initialisation or it might be an operators response to a prompt from one of the function keys. These keys allow the user to request waypoint functions (entry, display, activation, deactivation), display selection (sensor data, system data, comparison data or UTM information), help information (general help or specific to a prompt if pressed in response to the prompt) and miscellaneous functions (change gyro mode, transparent mode to the MX1107).

The primary objective of the KPU was that it should be user-friendly. To achieve this objective, several techniques were used. First, the system automatically entered the startup sequence on power-up and function keys allowed the user to select the area of interest. Prompts tell the user what input is required and default answers to the prompt show the response format and provide easy responses for most prompts. An on-line help function key gives a more detailed explanation of a prompt if pressed in response to the prompt (it gives general help if no response is requested). Finally, all user input is echoed to provide positive visual feedback of input. As well, rubout and clear keys allow corrections to be made quickly and easily. Reference 2.1.5 provides a more detailed description of these features.

The KPU task accepts input from the user, either in response to a prompt or triggered by a function key. Once a function is initiated (through the function key), it leads the user (prompts) through all the steps necessary to implement the function. At that point, the information is given to the appropriate task for implementation and the KPU waits for the next user request. Figure 10 illustrates the general work cycle of the KPU task.

6.2.6 Display Task (CDU)

The Display Task (CDU) formats all data shown on the central display unit and on the driver/commander displays. The formatting of the data involves selecting the information from the proper data structure, converting the data into the appropriate units and sending the data to the correct field of the display at the appropriate intervals. The driver/commander display is sent position, heading and desired heading on a continuous (every second) basis. The central display is sent time, position, heading, speed, status and desired heading on a continuous (every second) basis. As well, the bottom three lines of the central display are used to display information selected by the user. This might be sensor data, comparison data, error states, filter states, waypoints or UTM information. The keypad task can allocate these three lines for itself (for prompts) and the display cannot use them until they have been deallocated.

The CDU task is a time-driven periodic task in the sense that at specific times it wakes up, checks to see if new displays or waypoints have been selected and then displays the requested data. Figure 11 illustrates the general work cycle of the CDU task.

6.2.7 Data Logger Task (LOGGER)

The Data Logger Task (LOGGER) is responsible for formatting binary data into a block suitable for transmission over a RS232 serial line. As well, the task requesting the data logging can specify that the data is to be time-stamped by the logger task.

The LOGGER task receives blocks of data for logging from various tasks. It treats these blocks as an array of bytes which are then split into most significant/least significant nibbles (a nibble is 4 bits). The nibbles are converted to the ASCII representation of a hexadecimal digit and this string of hex digits is transmitted over the serial line.

The following table summarises the sizes of the application tasks in the PLANS system.

TASK	Lines of Code	Object Size(bytes)
KPU	3100	27000
CDU	900	12000
NAVGTR	900	11000
KALMAN	2100	30000
DCT	850	7500
TTI2	100	700
LOGGER	200	750
Library	1200	11000
RAM		32000
Non-Volatile RAM		1000

6.3 Inter-Task Communication

Inter-task communication generally fits into one of the following five categories:

- Initialisation data
  - from the keypad task to the data collection task, navigator task and filter task
- Operator data
  - from the keypad task to the display task
- Raw data
  - from the data collection task to the navigator task

- Prefiltered data
  - from the navigator task to the filter and display tasks

- Processed data
  - from the filter task to the display, navigator and data collector tasks

All of the above data also goes to the data logger for recording on cassette (/magnetic tape/winchester/etc.) to allow post-analysis.

The Data Flow Diagrams Level 1 and 2 with an associated Data Dictionary, in reference 2.5.3, give a more detailed description of data flow within the PLANS system.

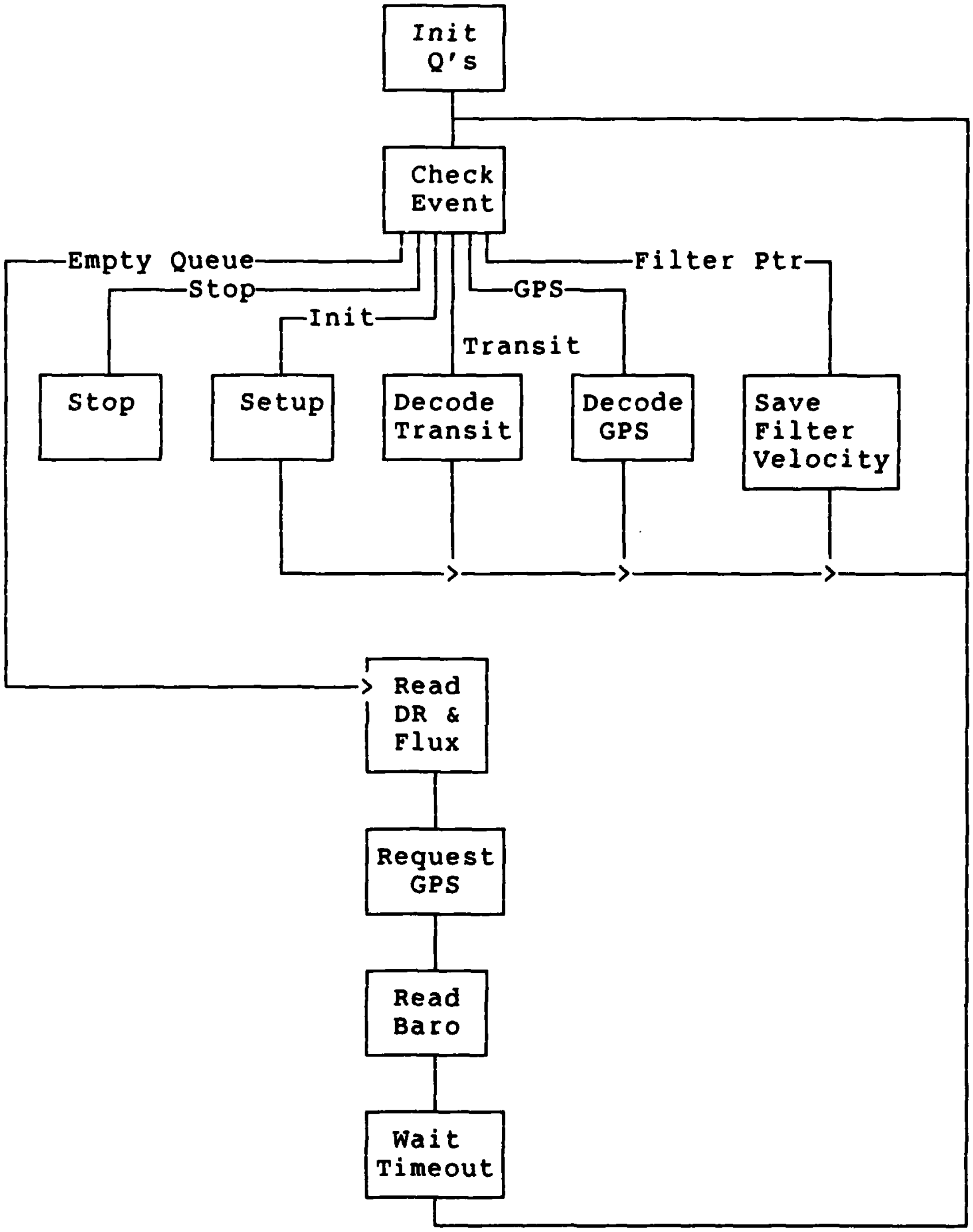

Figure 6. Data Collection Task

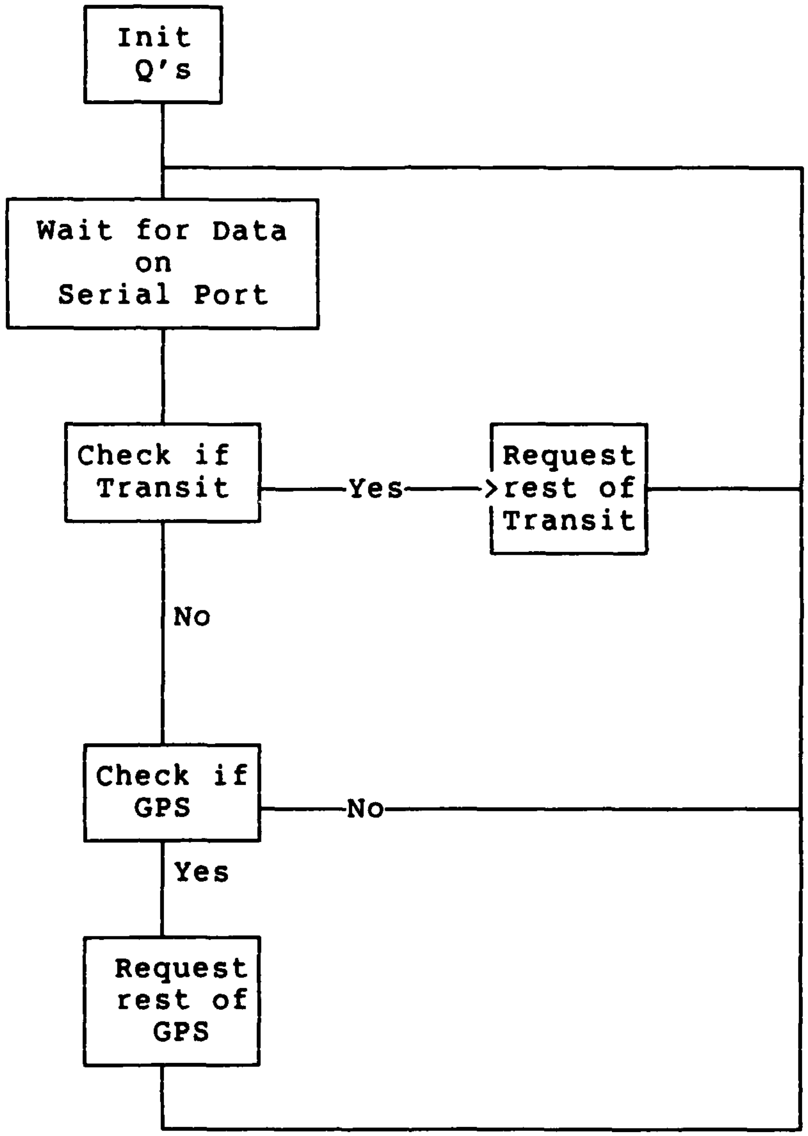

Figure 7. Serial Port Listener

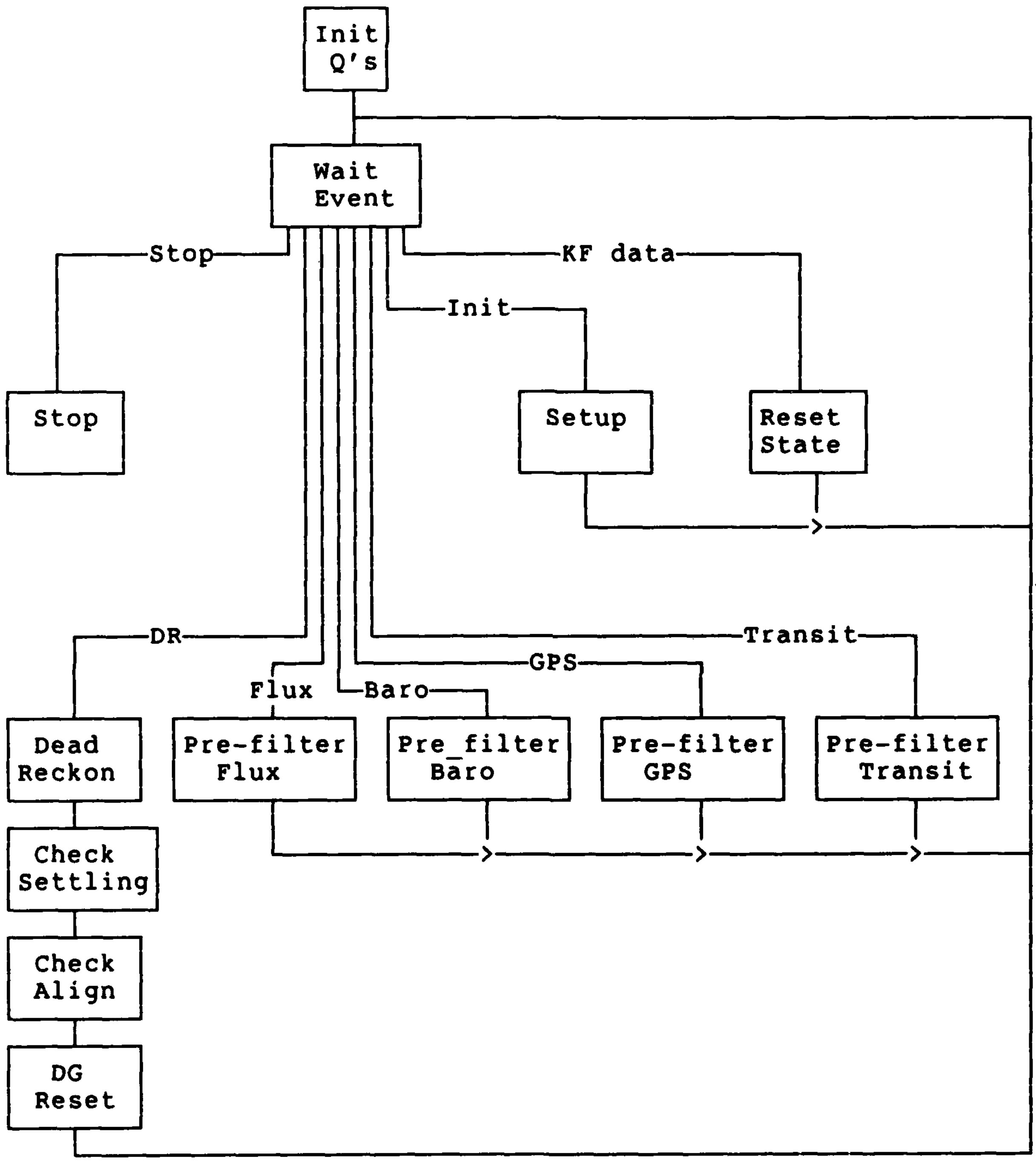

Figure 8. Navigation Task

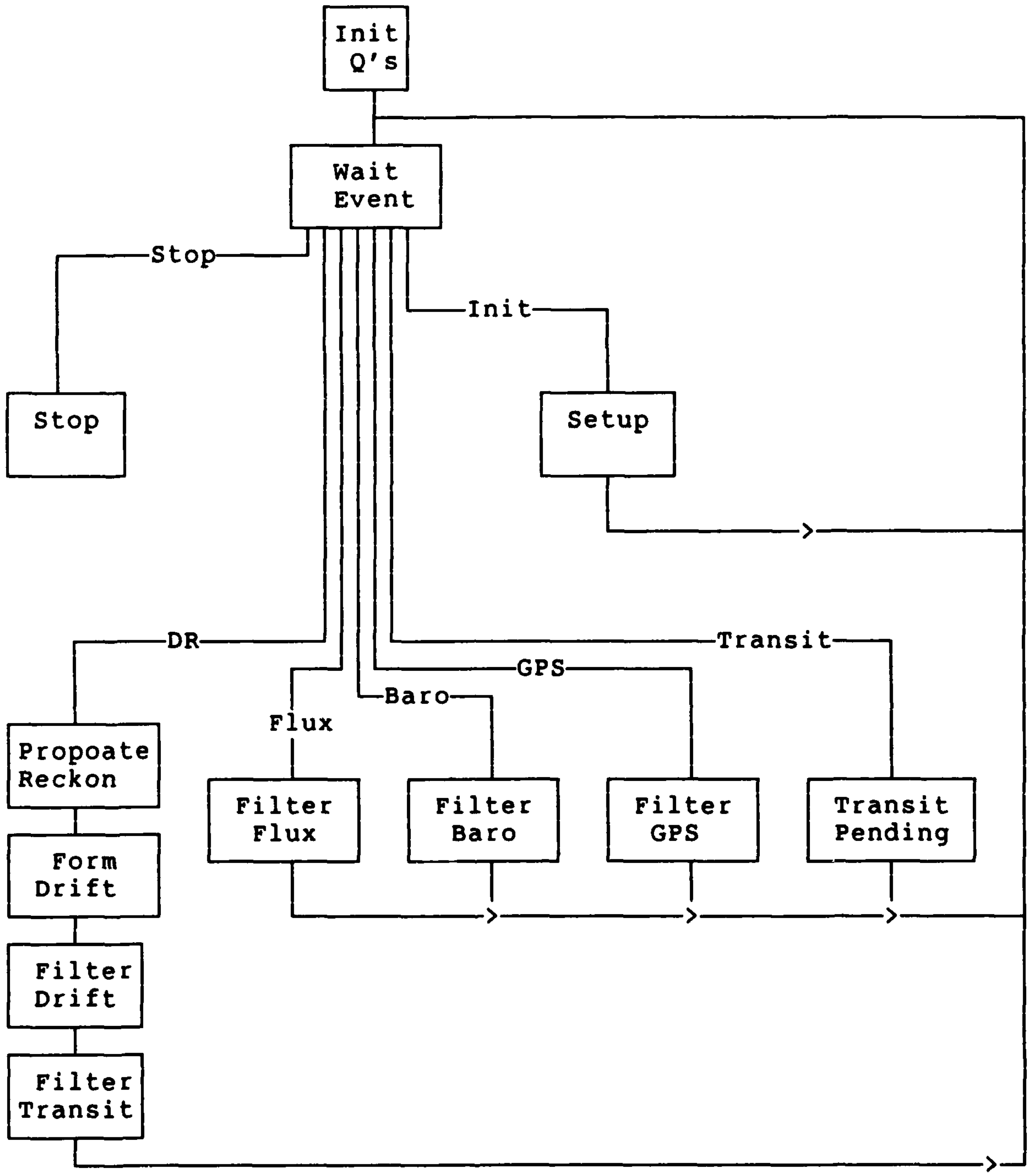

Figure 9. Kalman Filter Task

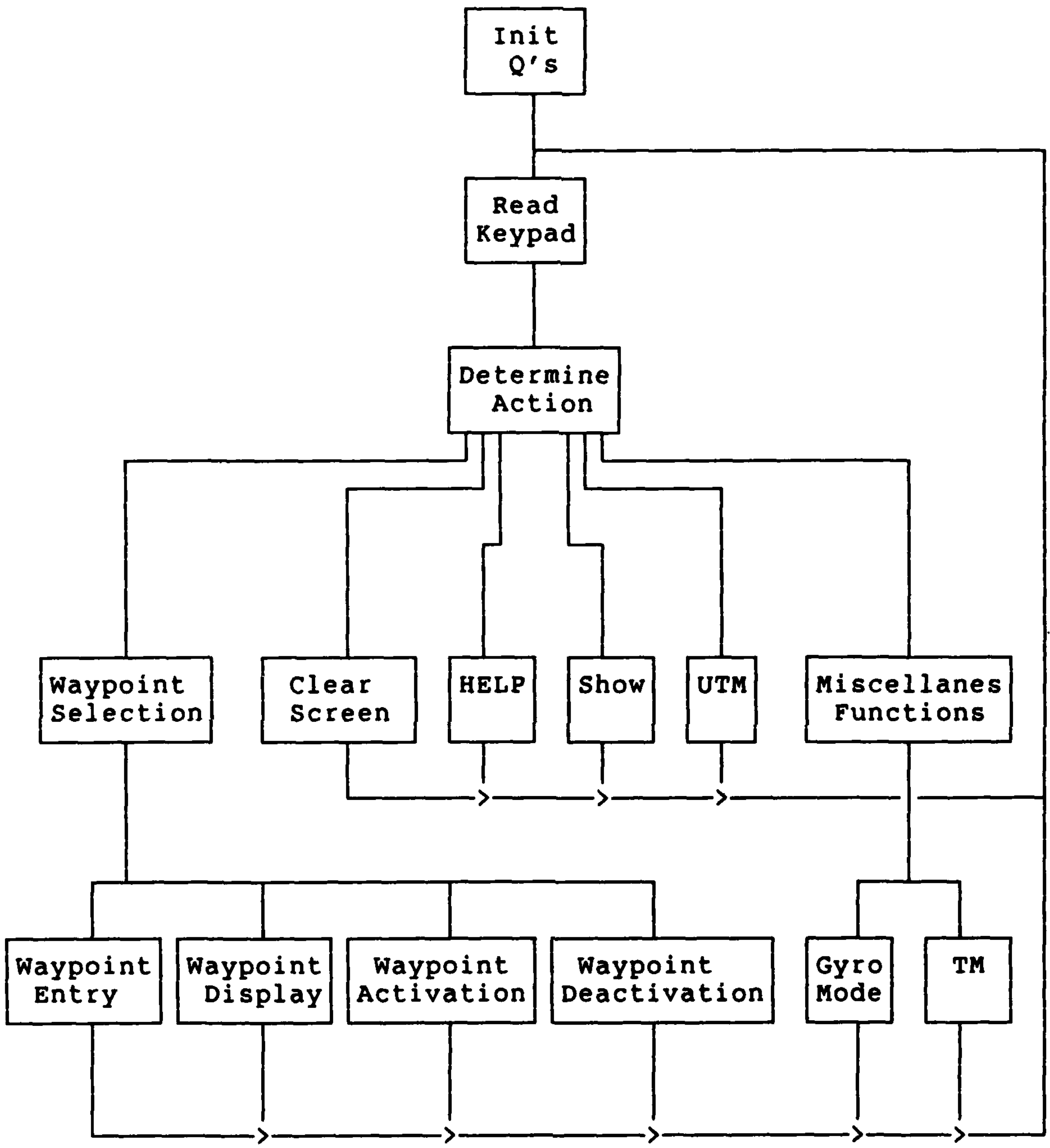

Figure 10. Keypad Task

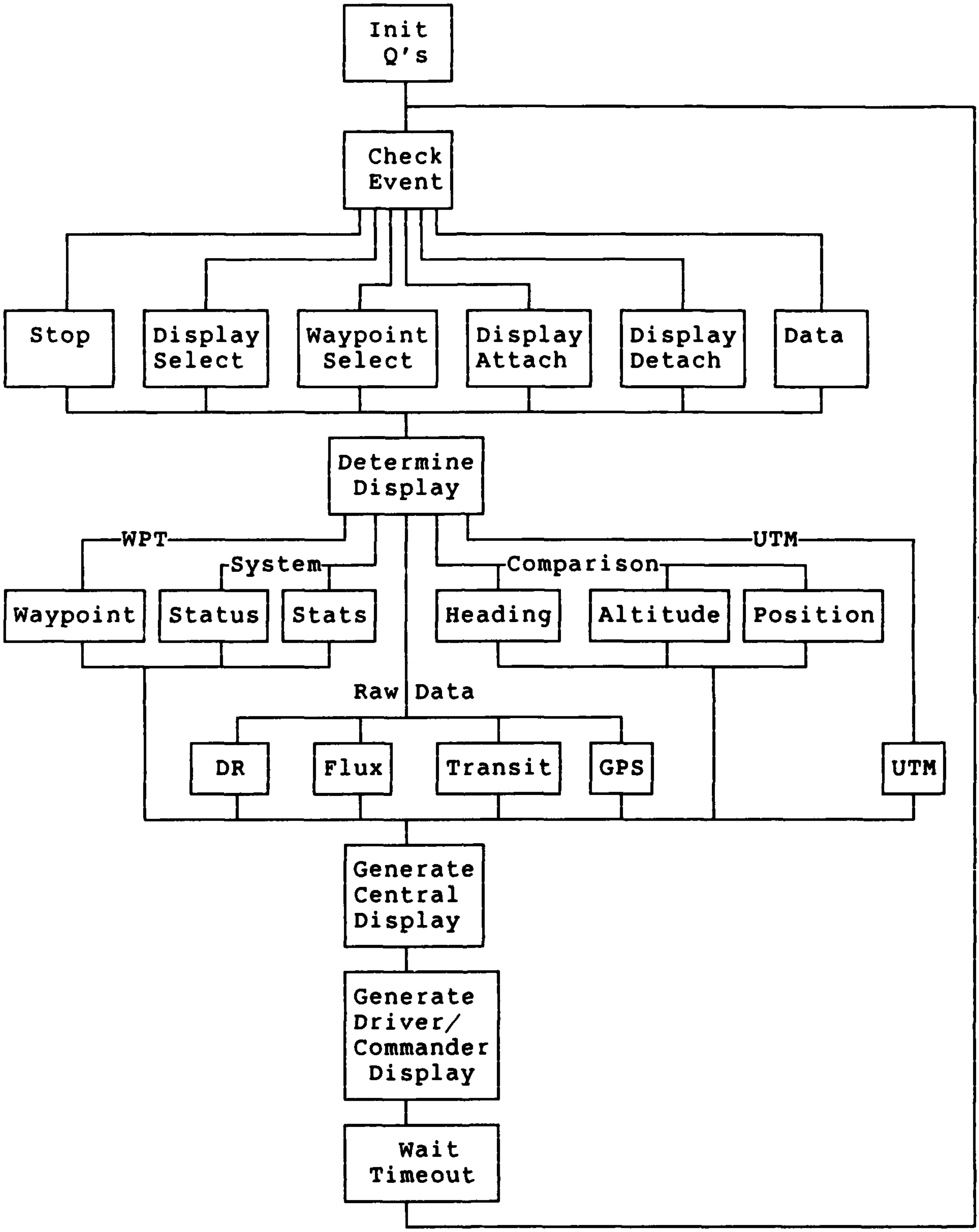

Figure 11. Display Task

7 PLANS PROCESSOR

The experimental development model (XDM) of the Primary Land Arctic Navigation System which has been built at DREO incorporates all the required characteristics along with some features useful during development and testing. This section gives a brief description of the XDM processor/interface hardware as configured during development.

7.1 Bus Configuration

The XDM was developed around a VMEbus configuration for high-speed access to the co-processor and memories. It also incorporates a secondary bus, the I/O Channel, to allow access to the slower I/O interfaces. All the VMEbus modules are of double-height Eurocard format (160 mm x 234 mm) and all I/O Channel interfaces are of single-height format (160 mm x 100 mm). The XDM chassis and backplane assembly has room for 5 VMEbus modules and 10 I/O Channel modules.

7.2 Processor/Accelerator

The processor module selected for PLANS is the Motorola MVME110. It is a high performance processing module using an MC68000 16-bit microprocessor running at 8 MHz. The module provides full support for the VMEbus addressing and control logic and will act as the system controller. It also provides support for the I/O Channel used in all the I/O operations. It also includes a RS-232C serial port and a triple 16-bit counter/timer. On-board sockets are used to provide 128 Kbytes of EPROM and 32 Kbytes of write-protectable RAM.

The XDM incorporates a Fast Floating Point Processor from SKY Computer (SKYFFP). It is a single board, double-width VME module that conforms to the IEEE single and double precision floating point standard. The SKYFFP is referenced by the CPU through a set of registers and therefore is not a true co-processor. The SKYFFP is compatible with multi-user environments. The SKYFFP performs the basic operations on single and double precision numbers and also some more complex operations (square-roots, trigonometric and transcendental) on single precision numbers. However, only the basic functions are used. Typical execution time for the basic functions is 4.5 μsec.

7.3 Memory

The XDM is built around a ROM-based microcomputer system. All the system software (real-time operating system, I/O drivers, libraries, etc.) and all the application tasks (Kalman filter, data collection, navigation tasks, etc.) are burnt-in EPROM. This is how the memory is partitioned. The CPU module holds four pairs of sockets, which provides 128 Kbytes of EPROM containing all the system software and 32 Kbytes of RAM containing the vector table and the operating system data base. An MVME201 module provides additional 256 Kbytes of RAM of which 48 Kbytes are allocated to the system pool where the tasks' stacks and local variables are assigned, 16 Kbytes are defined as the user pool where additional local or sharable memory can be dynamically allocated to tasks, 64 Kbytes are used to download new system software in development and 128 Kbytes used to download new application software or diagnostics during development. An MVME211 module populated with 2764 or 27128 EPROM provides up to 256 Kbytes of permanent data storage for the application tasks and diagnostics. An MVME210 module fully populated with non-volatile RAM also provides 32 Kbytes permanent read/write memory of which 24 Kbytes are used to download new version of the operating system during development and 1 Kbyte is used as a permanent save area by the application tasks. All the MVME modules are built by Motorola.

7.4 Future Processor/Interface Requirements

The XDM was developed and built at DREO over a number of years. A VMEbus configuration with I/O Channel capability was selected at the beginning though very few boards were available at the time. We have seen in the last few years a proliferation of VMEbus products and now hundreds of vendors offer a wide variety of VMEbus products and components. Better performance can now be achieved with fewer boards and at cheaper cost. A wide selection of I/O interfaces are now available for the VMEbus.

7.4.1 Processor/Memory

The PLANS ADM processor and its associated floating point co-processor or accelerator should have a throughput at least equal to the XDM and use one of the Motorola 68000-family microprocessors. The system would preferably be VMEbus-based. The system should include at least 256 Kbytes of EPROM, 32 Kbytes of system RAM, 64 Kbytes of user RAM and 1 Kbyte of non-volatile RAM. Software updates should be easily applied.

7.4.2 I/O Interfaces

I/O Interfaces for all the sensors and peripherals are obviously required. Whether they interface to VMEbus or the I/O Channel has still to be defined and will depend on availability and cost effectiveness.

7.4.3 Expansion

The system should provide several empty VMEbus slots for future enhancements or updates.

8 ACKNOWLEDGEMENTS

I would like to acknowledge the contributions of David DiFilippo who conducted a preliminary study of the problem, Barry Fletcher and Marc Dion who helped in the building and testing of the PLANS XDM, Mike Vinnins who contributed to the sensor and system testing and especially Arthur Ficko who designed the real time data processing software and helped implement the navigation, prefilter and filter software.

I would also like to thank Dr. David Liang for his guidance and support throughout the development and testing of PLANS. Of course thanks are also due to Steve Czyrnyj of DLAEEM 3-2 for his constant support and to the staff at DLR 4.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence Research Establishment Ottawa Shirley Bay Ottawa, Ontario	2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable) UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

Implementation of the DREO PLANS (Primary Land Arctic Navigation System) Experimental Development Model (U)

4. AUTHORS (Last name, first name, middle initial)

McMillan, J. Christopher

5. DATE OF PUBLICATION (month and year of publication of document) Sept 1988	6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 50	6b. NO. OF REFS (total cited in document) 34

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

DREO REPORT

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

DLAEEM 3-2 NDHQ

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) 041LJ	9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DREO REPORT 987	10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

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This Report gives a brief background summary of the PLANS development program, and provides a general description of the DREO Experimental Development Model (XDM) of a Primary Land Arctic Navigation System (PLANS). This includes a generic description of the essential PLANS hardware requirements (processors, memory, interfaces, displays, sensors etc.) as well as the specific hardware used in the XDM. A high level description of the software structure and data flow is given. A brief general description of the salient functional characteristics of PLANS is presented, including the accuracy performance. Also provided is an extensive list of references for further detailed information on the various components of the PLANS XDM.

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Navigation
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Arctic
Integrated System
Kalman Filter